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ORIGINAL PAPER

A preliminary study on the effects of line and selective thinning on bird communities in Hokkaido, northern Japan

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Abstract: In Japan, selective thinning is a common thinning method, though line thinning receives much attention because of its economic merits. In this study, we examined effects of the two thinning methods on bird communities in Todo fir (*Abies sachalinensis*) plantations in Hokkaido, Japan. We surveyed bird species in forests under four different management types – unthinned, selectively thinned, line-thinned plantation, and naturally regenerated forest (here after referred to as natural forest) stands – using a line-transect method. We also investigated vegetation structure (canopy tree and understory) of these stands. Bird species richness did not differ between natural forests and plantations, while bird total abundance was greater in plantations than in natural forests. Bird species richness and total abundance were comparable among the three management types for plantations. Abundances of 10 bird species were different among the four management types, and five species were more abundant in line-thinned plantations. However, two species were more abundant in selectively thinned stands than in line-thinned stands, and they frequently appeared in natural forests. There were no distinct differences in vegetation structure among the management types for plantations. Our results suggest that line thinning could be beneficial for some bird species in plantations.

Keywords: line thinning; selective thinning; Todo fir (*Abies sachalinensis*) plantation; improved indicator species analysis; bird community

Introduction

Approximately 42% of Japanese forests are plantations, most of which are mature. However, the country's timber self-sufficiency rate is only around 25%–30% and the Japanese government is attempting to raise it (Forestry Agency of Japan 2010). Thus, there is an increasing need to manage plantations sustainably. Thinning is an essential management practice for plantation forests (Nyland 2002). Today, selective thinning is a common thinning method in Japan, but in some cases, this method is not practical, as it requires skillful foresters, and it is time-consuming to select and harvest appropriate trees. For these reasons, line thinning, also called as row thinning or systematic thinning, is often preferred (Forestry Agency of Japan 2010). Line thinning is a thinning method by which linear sections of a plantation are harvested along the direction of slope or planting line. Line thinning saves time as well as effort of selecting trees and simplifies logging and transport of timber. This method also increases efficiency by introducing high-performance forestry machines. Additionally, after line thinning, the logged sections can be used as skid roads for next thinning (Forestry Agency of Japan 2010). Therefore, line thinning is often used worldwide (e.g., Nyland 2002; Mäkinen et al. 2005)

There are several studies on effects of thinning on animal populations that focus on selective thinning or line thinning. For example, selective thinning enhances species richness and abundance of insects (Ohsawa 2004; Taki et al. 2010), and line thinning enriches abundance of insects (Maleque et al. 2007). However, because the number of previous studies is limited, general applicability of these findings remains unknown. Furthermore, there have been no studies comparing effects of selective thinning to line thinning on animal communities.

Bird–habitat relationships have been examined by many studies in both naturally regenerated and man-made forests (*e.g.,* Wiens 1989; Lindenmayer and Hobbs 2004). A recent meta-analysis showed that number of individuals and bird species present in plantations was positively correlated with complexity of vegetation structure (Nájera and Simonetti 2009). Contrary to selective thinning, which creates small gaps in forest, line thinning creates large gaps. Different gap sizes alter structure of understory vegetation (Phillips et al. 1990; Wang and Liu 2011) and associated animal communities (Forsman et al. 2010). Hence, line thinning may promote understory vegetation growth and

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encourage a more diverse bird community than found in selectively thinned forests.

Todo fir (*Abies sachalinensis*) is the primary species found in plantation forests in Hokkaido, Japan. Approximately 52% of plantations include this species in Hokkaido (Forestry Agency of Japan 2007). Because Todo fir is an evergreen species, some reports have found that diversity and biomass of understory vegetation in Todo fir stands are limited without thinning due to lack of sunlight (*e.g.,* Kon et al. 2007). Thus, thinning may be an important practice for improving development of understory vegetation and increase bird diversity in Todo fir plantations. Therefore, we compared effects of three thinning methods (unthinned, selectively thinned and line-thinned) on bird communities within Todo fir plantations. To clarify cause of bird responses, we surveyed vegetation structure within the studied stands. In addition, we also conducted surveys in naturally regenerated forests (hereafter referred to as natural forests) and used natural forests as a reference habitat. The plantation forests in the study sites were surrounded by natural forests, which is a common situation in Hokkaido.

Materials and methods

Study sites

Our study area is located at the towns of Tobetsu (43°46′N, 141°63′E, 80–300 m a.s.l.) and Tsukigata (43°37′N, 141°66′E, 135–370 m a.s.l.) within Hokkaido Prefecture, Japan. Shinshinotsu (43°13′N, 141°39′E, 9 m a.s.l.), the meteorological station nearest to study sites in Tobetsu (–20 km), receives 943.5 mm of precipitation per year, and the mean annual temperature is 7.6°C. Tsukigata receives 1249.5 mm of precipitation per year, and the mean annual temperature is 7.2°C.

We selected 15 stands in three management types for Todo fir plantations. We selected five unthinned stands (UT), five selectively thinned stands (ST), and five line-thinned stands (LT). Todo firs in the selected stands were planted between 1962 and 1978. Mean stand age for UT was 43.6 years, 44.2 years for ST, 35 years for LT. Tree heights of Todo firs in the selected stands were approximately 10–20 m. In ST, Todo firs were thinned relatively uniformly across entire stands. According to the previous studies conducted in plantations and natural forests, density of bird species which depend on shrub and understory plants increases sharply 2–3 years after thinning or selective logging (Robinson and Robinson 1999; Hayes et al. 2003). Thus, we selected thinned stands that had been thinned 2–3 years previously. The thinning intensity resulted in a reduction of approximately 30% in volume for each of the thinned stands. We also selected three stands of natural forests (NF). Therefore, this study included four management types (Supporting Information Appendix 1). Tree heights of upper layers in NF were approximately 20 m and sparse canopy structure of NF suggests that NF had been selectively logged previously. The primary tree species that dominate the natural forests are native deciduous, broad-leaved trees, such as *Quercus crispula, Tilia japonica*, *Betula maximowicziana, Kalopanax pictus*, and *Acer mono* var. *mayrii.*

Before sampling birds, we set up one 200-m long transect in the centre of each selected stand. We marked the start and end points as well as either two or three mid-points using vinyl marking tape. We established transects irrespective of direction of the thinned rows in LT because some LT were not large (<5 ha), constraining place of the transects. Though we were able to set up the transects and survey birds along them within the plantations (approximately 20 m far from forest roads), this was quite difficult in natural forests because of the thick cover of dwarf bamboo (e.g., *Sasa* spp.). Therefore, we set up transects along forest paths for forest management in the natural forests. These forest paths were approximately 4–5 m in their width and did not seem to affect forest structure. All transects were spaced at least 350 m apart. All of the selected plantation stands were not so large, extending approximately 150 m in width.

Bird sampling

We visited each transect three times and identified bird species using a line-transect method (Bibby et al. 2000). We walked each of the 200-m transects and recorded all of the individuals seen or heard within 50 m on each side of the transect. It is suggested that bird detection rates within 50 m are similar even among the plots with different vegetation structure (Schieck et al. 1997; Alldredge et al. 2007). We sometimes stopped and carefully searched for birds because the noise made by shoes and understory plants prevented the observer from detecting birds while walking. Birds flying over and through the forests were not counted. We conducted bird surveys between sunrise and 10 a.m. and surveys were not conducted on the days with either rain, fog or strong wind. Each transect was visited three times on different days and different time (early and late period of census time). We visited several transects in one day and determined the order of visits to implement bird census efficiently. The census period was between June 26th and July 20th, 2010. Because bird censuses in breeding season have been conducted between late April and late July in Hokkaido (Murakami et al. 2008; Tamada 2010; Fujimaki 2011), our sampling period was late season for breeding birds. The identification and recording of birds were conducted by single person (Y.T.), but the survey was always conducted with one attendant for safety reasons (Brown bear, *Ursus arctos*, wander into the study area).

Vegetation sampling

We measured vegetation structure in four transects (25 m × 4 m) at each selected stand. Transects for vegetation sampling were set up along the transects for bird sampling, but spaced 5 m apart to avoid disturbance of preceding bird surveys (the observer had walked on vegetation). Neighbouring transects were spaced 25 m apart. We estimated coverage (%) and height (m) of herbaceous vegetation (herbs), dwarf bamboo, woody shrubs and ferns. We also estimated canopy cover (%), number of stems and species and diameter at breast height (DBH) of trees and lianas. We define shrubs as woody plants ≤3 m tall and trees as woody plants

≥5 cm in DBH. For lianas, we identified individuals ≥2 cm in DBH. Canopy cover, as well as coverage and height of herbs, dwarf bamboo, shrubs and ferns, were estimated visually by one person (Y.T.). The survey was conducted between October 5th and October 20th, 2010.

Statistical analyses

For each bird species, we used maximum number of individuals (adult birds) observed at each transect within the three visits as abundance of each species at each transect (*e.g.,* Hausner et al. 2003). To examine differences in species richness, abundance of all bird species and abundance of each bird species among the four management types (*i.e.,* UT, ST, LT, and NF), a likelihood ratio test was conducted using a generalised linear model (GLM) with a Poisson error structure. Likelihood ratio test was also conducted among the plantation management types. To determine species associated with specific management types, an indicator species analysis (INSPAN) was conducted. INSPAN has been used to reveal association between species and a single habitat type (Dufrêne and Legendre 1997). Recently, De Ćaceres et al. (2010) improved INSPAN to examine association between species and multiple habitat types. We conducted this updated INSPAN using 'indicspecies' R package Ver. 1.5.1 (De Ćaceres and Jansen 2010). We used *rpb* as the association index to take into account species absences (De Ćaceres et al. 2010). Because we could not differentiate between marsh tit (*Parus palustris*) and willow tit (*Parus montanus*) in the field, we grouped these species as marsh tits. For the likelihood ratio test for each species and for INSPAN, we analysed bird species represented by at least five individuals during the census period.

To examine difference in vegetation structure among the four management types and among the plantation management types, we conducted a one-way analysis of variance (ANOVA) for 11 variables that represent vegetation structure. Canopy cover, mixing ratio of broad-leaved trees (number of broad-leaved trees/ number of all trees), coverage and height of herbs, dwarf bamboo, shrubs and ferns were calculated from the average value of the four transects for each stand. We calculated volume of herbs, dwarf bamboo, shrubs and ferns using cover × height × 4 × surveyed zone (4 m × 25 m = 100 m^2). Number of stems on Todo fir, liana, snags and basal area of Todo fir and trees were calculated from total number of the four transects for each stand. We compared number of stems on Todo fir, basal area of Todo fir and mixing ratio of broad-leaved trees only among the plantation management types. The significance level for all of the analyses was set at 10%.

Results

Differences in bird communities among management types

A total of 33 bird species was found in the forests we surveyed (Table 1). Bird species richness did not differ among our four management types. Abundance of all bird species differed among four management types, but we did not find difference in bird abundance among plantation management types (Fig. 1a, b, Table 1). Bird abundance in NF was less than that in the plantations. Species richness and abundance in UT had large variances.

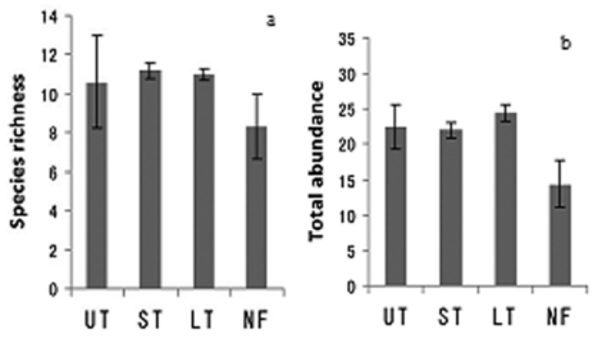

Fig. 1 (a) Species richness, (b) total abundance among the four management types – unthinned stands (UT), selectively thinned stands (ST), line-thinned stands (LT), naturally regenerated forest stands (NF). Error bar represents standard error (SE) for each management type.

Among the four management types, we found significant differences in abundances of 10 of 18 species compared, including the great spotted woodpecker (*Picoides minor*) and the goldcrest (*Regulus regulus*). Five species appeared less frequently in the NF than in the plantations, including the black-faced bunting (*Emberiza spodocephala*) and oriental greenfinch (*Carduelis sinica*). Four species, the great spotted woodpecker, goldcrest, Japanese grey bunting (*Emberiza variabilis*), and brown flycatcher (*Muscicapa latirostris*) appeared more in LT than in UT or ST. The great tit (*Parus major*) and marsh tit appeared more frequently in the ST and NF than in the LT. INSPAN revealed that the great spotted woodpecker, goldcrest and coal tit were associated with one or more management types (Table 1). The great spotted woodpecker and goldcrest were only associated with LT; the coal tit was associated with both UT and LT.

Management types and vegetation structure

ANOVA indicated that four variables, canopy cover, volume of dwarf bamboo, basal area of trees and number of snags, differed among the four management types (Table 2). Volume of dwarf bamboo, basal area of Todo fir and trees and number of stems on Todo fir and snags were different among plantation management types. The number of stems on Todo fir and the basal area of trees in the ST were smaller than those in both the UT and LT. Canopy cover in the NF was the lowest among the management types. The volume of dwarf bamboo was consistently larger in the NF than in the plantations and was largest in the ST among the plantation management types. The volumes of herbs, shrubs and ferns in the ST, and the herbs and shrubs in the LT had large variances. The number of snags in the UT and LT was greater than those in the other management types.

Table 1. Abundances of all birds and each species, species richness and standard error (SE) in four management types and the result of the likelihood ratio test (LT) and indicator species analysis (INSPAN).

Bird species	UT	SE	ST	SE	L	SE	NF	SE	LT1 (d.f. = 3)	LT2 (d.f. = 2)	INSPAN	
									χ^2	χ^2	Type	r_{pb}
Black-faced bunting (*Emberiza spodocephala*)	4.6	0.8	4.4	0.7	3.4	0.9	1	0.6	10.08**	1.03	USL	0.66**
Japanese green pigeon (*Treron sieboldii*)	0	0	0	0	0	0	0.3	0.3	n.a.	n.a.	n.a.	n.a.
Great spotted woodpecker (*Picoides major*)	0	0	0.6	0.2	1.4	0.4	0.3	0.3	10.28**	9.76***	L	0.64**
Brown thrush (*Turdus chrysolaus*)	1	0.3	0.8	0.6	0.4	0.2	0.7	0.7	1.39	1.37	US	0.21
Masked hawfinch (*Coccothraustes personatus*)	0.4	0.2	0	0	0.2	0.2	0	0	n.a.	n.a.	n.a.	n.a.
Japanese bush warbler (*Cettia diphone*)	0.4	0.2	0.2	0.2	0	0	0.3	0.3	n.a.	n.a.	n.a.	n.a.
Pale-legged willow warbler (*Phylloscopus tenellipes*)	0.2	0.2	0.2	0.2	0.2	0.2	0	0	n.a.	n.a.	n.a.	n.a.
Eurasian jay (*Garrulus glandarius*)	0.2	0.2	0	0	0	0	0	0	n.a.	n.a.	n.a.	n.a.
Oriental greenfinch (*Carduelis sinica*)	0.4	0.2	0.8	0.4	1.6	0.6	0	0	9.11**	4	L	0.54
Goldcrest (*Regulus regulus*)	1.6	0.7	1.6	0.9	3.4	0.7	0	0	16.64***	4.61*	L	0.56*
Eastern turtle dove (*Streptopelia orientalis*)	0.4	0.4	0.2	0.2	0.4	0.2	0	0	2.26	0.44	UL	0.28
Grey wagtail (*Motacilla cinerea*)	0	0	0	0	0	0	0.3	0.3	n.a.	n.a.	n.a.	n.a.
Treecreeper (*Certhia familiaris*)	0.2	0.2	0	0	0	0	0	0	n.a.	n.a.	n.a.	n.a.
Narcissus flycatcher (*Ficedula narcissina*)	0.6	0.4	0.6	0.2	1.2	0.2	1.3	0.3	2.13	1.41	LM	0.51
Black woodpecker (*Dryocopus martius*)	0.2	0.2	0	0	0	0	0	0	n.a.	n.a.	n.a.	n.a.
Japanese grey bunting (*Emberiza variabilis*)	0.2	0.2	0	0	0.8	0.8	1	1	7.97**	5.98*	LM	0.34
Japanese grey thrush (*Turdus cardis*)	0	0	0.2	0.2	0	0	0.7	0.3	n.a.	n.a.	n.a.	n.a.
Japanese pigmy woodpecker (*Picoides kizuki*)	0	0	0.6	0.2	0	0	0.3	0.3	n.a.	n.a.	n.a.	n.a.
Blown flycatcher (*Muscicapa latirostris*)	0	0	0.4	0.4	0.8	0.8	0	0	7.73*	5.55*	SL	0.31
Siberian blue robin (*Erithacus cyane*)	1.8	0.6	1.2	0.7	0.8	0.2	0.3	0.3	4.57	2	US	0.41
Great tit (*Parus minor*)	0	0	0.8	0.4	0	0	0.7	0.7	9.78**	8.79**	SM	0.52
Hawfinch (*Coccothraustes coccothraustes*)	1	0.4	0.2	0.2	0.8	0.4	0	0	6.75*	3.11	UL	0.54
Eastern crowned willow warbler (*Phylloscopus coronatus*)	0.8	0.4	0.8	0.4	0.6	0.2	1	0.6	0.4	0.19	USM	0.16
Oriental cuckoo (*Cuculus saturates*)	1	0.4	0.6	0.2	1	0.3	0.7	0.3	0.78	0.66	UL	0.27
Marsh tit (*Parus palustris, Parus montanus*)	0	0	1	0.4	0.2	0.2	2	2	14.83***	7.78**	SM	0.41
Jungle crow (*Corvus macrorhynchos*)	0.2	0.2	0	0	0.2	0.2	0	0	n.a.	n.a.	n.a.	n.a.
Carrion crow (*Corvus corone*)	0	0	0.4	0.4	0.2	0.2	0	0	n.a.	n.a.	n.a.	n.a.
Coal tit (*Parus ater*)	2	0.7	1	0.3	2	0.3	0.3	0.3	6.41*	2.18	UL	0.59*
Brown-eared bulbul (*Hypsipetes amaurotis*)	0.4	0.4	0.4	0.2	0	0	0.7	0.7	4.23	3.24	USM	0.3
Long-tailed rose finch (*Uragus sibiricus*)	0.2	0.2	0.4	0.2	0	0	0	0	n.a.	n.a.	n.a.	n.a.
Japanese white-eye (*Zosterops japonica*)	0.2	0.2	0	0	0	0	0	0	n.a.	n.a.	n.a.	n.a.
Short-tailed bush warbler (*Cettia squameiceps*)	0.8	0.4	1	0.5	0.2	0.2	0.7	0.3	3.11	3.11	USM	0.34
Varied tit (*Parus varius*)	0.2	0.2	0	0	0	0	0	0	n.a.	n.a.	n.a.	n.a.
Species richness	11	2.4	11	0.4	11	0.3	8.3	1.7	1.79	0.09	n.a.	n.a.
Abundance	22	3.2	22	1.1	24	1.2	14	3.3	10.25**	0.71	n.a.	n.a.

Note: *: p <0.1, **: p <0.05, ***: p <0.01. UT: unthinned stands, ST: selectively thinned stands, L: line-thinned stands, NF: naturally regenerated forest stands. LT1 and LT2 show LT among all management types and among plantation management types, respectively. As for INSPAN, we describe management types associated with each species. We calculated mean abundance of all bird species and each bird species and mean species richness of each management type. We use these values as abundance and species richness in this table.

Discussion

Bird communities in plantations and natural forests

A recent meta-analysis showed that bird species richness in natural forests is higher than that in plantations (Nájera and Simonetti 2009). In the present study, bird species richness and abundance in natural forests were not larger than those in plantations. The more complex the vegetation structure, the greater the bird species richness in natural forests and plantations (e.g., MacArthur and MacArthur 1961; Nájera and Simonetti 2009). Among components of understory, herbs and shrubs were important in maintaining many bird species (Yamaura et al. 2008b). In our study sites, the volumes of herbs and shrubs in natural forests were

comparable to those in plantations, suggesting that structural complexity in understory vegetation of plantations might not be inferior to natural forests. We attribute the low volumes of herbs, shrubs and ferns in the NF to the thick stands of dwarf bamboo, which is important only to a few species (*e.g.,* Japanese bush warbler, *Cettia diphone*; Yamaura et al. 2008b). Though the NF might be a good environment for understory vegetation growth because of its low canopy cover, dwarf bamboo would shade light and reduce growth of other vegetation. Because NF seemed to have been selectively logged previously, structural complexity of upper layers may have been negatively affected. This may also lead to relatively low species richness and abundance in the NF (see also Gibson et al. 2011). Additionally, seedeaters that prefer coniferous plantations, such as the hawfinch and oriental greenfinch (Yamaura et al. 2005*,* 2008a), and species that prefer conifers, such as the goldcrest (Yamaura et al. 2009), appeared only in the plantations. These species contributed to high species richness and abundance in the plantations. Because birds in broad-leaved forests are able to forage in adjacent plantations, bird species richness and density are high in plantations adjacent to broad-leaved forests (Tubelis et al. 2004). Our studied stands in the plantations were all surrounded by natural forests. Thus, many birds could fly from them to plantations, which would further enhance species richness and abundance in the plantations.

Nájera and Simonetti (2009) suggested that structurally complex plantations could support a higher bird species richness and abundance than natural forests with simple complexity. Thus, the similar results from the present study may not be so rare depending on stand structure.

Table 2. Average value (Avg.) and standard error (SE) of 11 variables of four management types from results of vegetation surveys and results from one-way analysis of variance (ANOVA).

		Canopy cover (%)	Volume of Herbs (m^3)	Volume of dwarf bamboo (m^3)	Volume of shrubs (m^3)	Volume of ferns (m^3)	Number of stems on Todo fir	Mixing ratio of broad-leaved trees (%)	Basal area of Todo fir (m^2)	Basal area of Trees (m^2)	Number of stems of Liana	Number of snags
UT	Avg.	70.5	9.7	111.8	26.2	12.4	33	11.6	1.7	2	5.6	6.8
	SE	3.5	3.2	22.1	4.3	4.5	2.5	4	0.3	0.2	1.4	0.7
ST	Avg.	55	49.7	192.6	44	24.6	17.4	22.4	1	1.2	4.6	1.8
	SE	2.6	27.6	51.7	24.3	14.5	2.7	8.5	0.1	0.1	1.7	0.7
LT	Avg.	56	30.5	62.3	77.1	3.5	37.4	5.7	1.3	1.4	4.6	5.8
	SE	7.9	10.2	14.6	30.6	1.1	3.7	2.5	0.1	0.1	1.7	1.2
NF	Avg.	27.9	21.8	609	74.8	5.7	2.3	n.a.	n.a.	0.8	7.3	0.7
	SE	12.5	8.7	129.9	24.8	3.7	1.5	n.a.	n.a.	0.1	0.7	0.7
ANOVA1	*F*	6.22	1.08	17.6	1.12	1.27	n.a.	n.a.	n.a.	7.8	2.32	9.55
	p	*		*						*		*
ANOVA2	*F*	2.8	1.37	3.85	1.29	1.46	12.4	2.3	3.75	5.69	0.12	8.02
	p			*			*		*	*		*

Note: *: p <0.1. ANOVA1 and ANOVA2 show the ANOVA among all management types and plantation management types, respectively. UT: unthinned stands, ST: selectively thinned stands, LT: line-thinned stands, NF: naturally regenerated forest stands, herbs: herbaceous plants.

Bird responses to different operations in plantations

In this study, bird species richness and abundance were comparable for all of the plantation management types. This may be attributed to similar understory vegetation structure, with the exception of dwarf bamboo, among the three plantation management types, which is contrary to the findings of previous studies. For example, Ishii et al. (2008) reported that biomass of woody and annual understory plants increased in thinned plantations. The primary reason for this discrepancy could be the large variance in the ST and LT, and there would be different factors from thinning such as site productivity (*e.g.,* Larson et al. 2008), which affect growth of understory vegetation in post-thinned forests.

In terms of bird species, the great spotted woodpecker, goldcrest, brown flycatcher, and Japanese grey bunting dominated the LT, more than the other plantation management types. Among these four species, INSPAN showed that the great spotted woodpecker and goldcrest were associated with the LT; therefore, this may be an important habitat for these species. These four species include the flycatchers (brown flycatcher) and species that forage in canopy of conifers (goldcrest). These species may use large open spaces that are created by line thinning. In addition, density of cavity-nesting birds, such as woodpeckers, increases with an increasing number of snags (Land et al. 1989; Yamaura et al. 2008b). Therefore, a large number of snags in the LT might contribute to occurrence of the great spotted woodpecker there. The coal tit appeared with comparable frequency in the UT and LT but appeared less frequently in the ST. Although reasons why these species positively responded to line thinning were not clear, abundance of some species may be increased by line thinning rather than selective thinning. The great tit, marsh tit and willow tit appeared more frequently in the ST and NF than in the LT. These species may be positively affected by medium-sized gaps (created by selective thinning), and avoid large-sized gaps created by line thinning. In any way, these species may be negatively affected by line thinning.

In Japan, selective thinning is a common thinning method today (Forestry Agency of Japan 2010). This study showed differences in bird communities among different thinning operations, suggesting that line thinning could be beneficial for some bird species in plantations. In this study, however, age of the Todo fir stands, number of stems on Todo fir and basal area of trees and Todo fir were different among the plantation management types. This is because line and selective thinning is adopted as first and second thinning, respectively, in this region. Additionally, bird and vegetation samplings were conducted in the late seasons. Therefore, results of our study should be tested in future studies because Japan has a vast area of plantations.

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Appendix. 1. Location of the studied stands in Tobetsu and Tsukigata town, Hokkaido, northern Japan. Unthinned stands (UT) are shown in green, selectively thinned stands (ST) in blue, line-thinned stands (LT) in red and naturally regenerated forest stands (NF) in yellow. Non-delineated area in the center of the map was non-forest. This map was described using GIS data provided by Hokkaido Prefecture.